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MUNICIPAL INCINERATOR DESIGN. A SURVEY OF ENGINEERING PRACTICE

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Municipal Incinerator Design

A Survey of Engineering Practices

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MUNICIPAL INCINERATOR DESIGN

A Survey of Engineering Practice

Prepared by the
Solid Wastes Engineering Section
Committee on Sanitary Engineering Research
AMERICAN SOCIETY OF CIVIL ENGINEERS

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

Bureau of State Services
Division of Sanitary Engineering Services General Engineering Program

FOREWORD

Sanitary solid waste disposal is basic to community sanitation.

Refuse has been shown to be an important factor as a breeding and sustaining medium for vectors of diseases of man. It has been demonstrated to be of importance in the actual transmission and spread of trichinosis of man and vesicular exanthema and other diseases of swine. It has been found to be a significant factor in the incidence of building fires in the United States. It appears to have considerable significance in certain areas in atmospheric and water pollution. Its potential nuisance factors, such as smoke and odors from improper disposal, are well recognized.

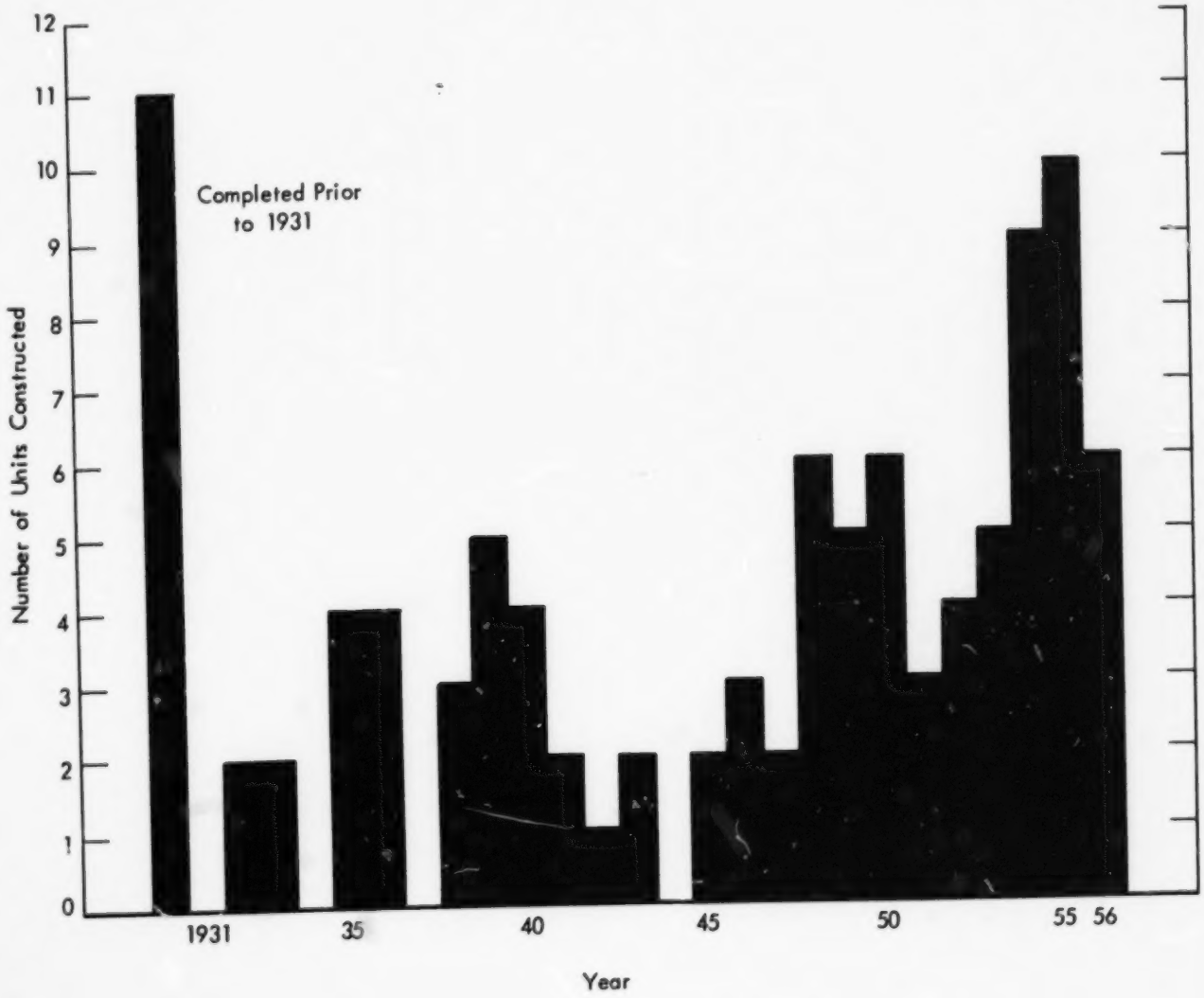
Incineration is a method of solid waste disposal which is particularly applicable to cities and metropolitan areas where available land for sanitary landfilling is depleted or not available. With the trend toward expanding urban areas and metropolitan complexes, incineration may well play an increasingly important part in solving community solid waste disposal problems.

Thus this study was undertaken to collect data on current engineering practice in this field to permit better evaluation of engineering and related needs.

Nelson R. Nemerow, Chairman,
Committee on Sanitary Engineering
Research, Solid Wastes Engineering
Section.
Ralph Stone, Head
Frank Bowerman
John Merrell, Jr.
Leo Weaver

Malcolm C. Hope, Chief,
General Engineering Program,
Division of Sanitary
Engineering Services,
U. S. Public Health Service.

Figure 1 YEAR CONSTRUCTION COMPLETED ON 100 INCINERATOR PLANTS REPORTED OPERATION, 1957



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INTRODUCTION

Recently questions have arisen concerning the adequacy of the basic incinerator plant design criteria available to meet today's municipal refuse disposal requirements. The Solid Wastes Engineering Section conducted this study to enable better evaluation of conditions in the refuse incinerator engineering field.

In March 1957 questionnaires were mailed to some 230 cities in the U. S. reportedly using incineration as a method of municipal refuse disposal. Replies were received from 110 cities, of which number ten reported using a plant operated by another city, county, or authority, and thirteen reported having abandoned their plants. Comprehensive replies were received from eighty-eight cities. Additional data published in tabular form in the literature permitted compilation of questionnaire data sheets for fourteen additional cities. Thus, the information contained in this report is based on an analysis of data on the newest or best plants currently operating in 102 cities in twenty-eight states and the District of Columbia. The breakdown of these cities according to population group is listed in Table I.

TABLE I
Number of Cities Reporting

Population Groups	Number of Cities
1,000,000 and over	5
500,000 to 1,000,000	10
100,000 to 500,000	25
50,000 to 100,000	16
25,000 to 50,000	17
5,000 to 25,000	29
Total	102

DISCUSSION

Trends in Construction

Figure one shows the year construction was completed on the newest or best incinerator plant in 100 cities (two cities did not report on this item). It is interesting to note that 11 or 11% of the plants were completed prior to 1931 and are over 25 years of age; 34 or 34% were constructed prior to 1946

and range from ten to 25 years old; and slightly more than half or 55% have been placed in operation during the past ten years.

It is of further interest that the 13 communities reporting abandonment of their plants did so since 1951 and eight reported the adoption of the sanitary landfill method. Ten of the 13 cities had less than 50,000 population. The dates of construction of the abandoned plants were reported in four instances; their ages when abandoned were 7, 16, 18, and 20 years respectively.

Figure 2 shows a graphic presentation according to population of the dates of completion of construction of the newest or best plant currently operating in 86 cities. The trend toward increasing utilization of incineration as a method of refuse disposal in the larger cities is significantly demonstrated.

It should be kept in mind in interpreting this data that it represents the newest or best plant in each city. Data received from the 88 basic study cities showed that 120 municipal incineration plants are in operation. It is estimated that about 145 plants are operated by the reporting group of 102 cities.

Responsibility for Engineering Plant Construction

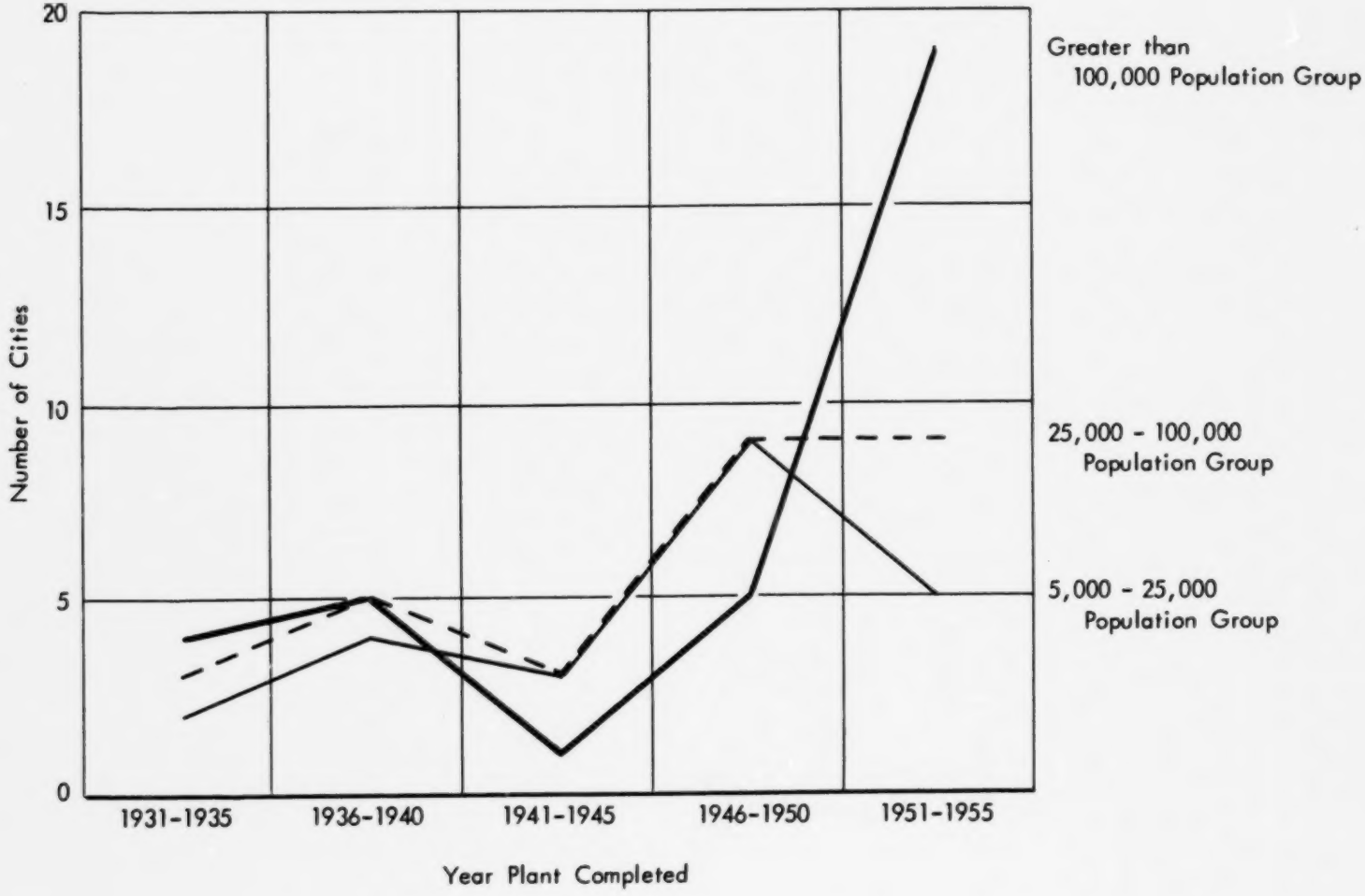
Eighty-eight cities provided information on where responsibility was centered for the engineering of the plants. Consulting engineers had primary responsibility in 54 or 62% of the cities. The municipal engineering staffs of 14 or 16% of the cities bore the responsibility for the design; the manufacturer in 17 or 19% of the cities, and the manufacturer and the city engineering staffs took this responsibility jointly in three or 3% of the cities. Of significance is the fact that in 34 or 39% of the cases reported, a consulting engineer was not involved in the design of the plant.

Seventy-nine of the 88 cities responded to the query "are you satisfied with the plant performance?" Sixty-nine reported, yes, ten, no. Of the ten plants reported giving unsatisfactory performance, seven were reported to have been designed and constructed without the services of a consulting engineer.

Type of Refuse Material Acceptable for Incineration

Garbage and combustible rubbish is the predominant classification of refuse accepted for burning at municipal incinerators. Combined or mixed

Figure 2 INCINERATION TRENDS ACCORDING TO POPULATION (86 Cities)



refuse is the second most important classification. Together, these two classifications represented 87% of the type material accepted at municipal incinerator plants. Table II lists the types of material accepted for burning in 97 cities. Four of the cities reported accepting garbage only. It is probable that this garbage is at least wrapped in paper and it is likely that combustible or non-combustible food containers are also included in the local definition of the term "garbage."

TABLE II
Type of Refuse Accepted for Incineration

Material	Number of Cities
Garbage and combustible rubbish	59
Combined or mixed refuse	25
Combustible rubbish only	9
Garbage only	4
Rubbish (combustible or non-combustible)	0
Total	97

Disposal of Incinerator Ash

Eighty-five cities reported on the ultimate disposition of incinerator ash. Of this number 65 or over 75% dispose of incinerator ash in sanitary landfills, only 20 reported that they did not. Of significance is the fact that 20 of the cities use the sanitary landfill method solely for the disposal of incinerator ash. Forty-five reported the use of the sanitary landfill not only for incinerator ash but also as a method of refuse disposal along with incineration.

Weighing of Refuse To Be Incinerated

Eighty-six cities reported on whether refuse to be burned was weighed. Forty-nine replied in the affirmative. Forty-three percent (37) reported that refuse was not weighed.

DESIGN DATA

Grates

Figure 3 is a graphic presentation of the type of grates used in 92 plants and the year they were placed in operation. The figure demonstrates the complete change in practice with respect to hand stoking with only one such plant being constructed during the past seven years. On the other hand reliance on automatic or semi-automatic grates is now apparently universally accepted practice. One rotary kiln type furnace was reported in operation. (Atlanta, Georgia) A second was placed in operation in 1957 at Louisville, Kentucky. The travelling grate type furnace represents a new development in municipal incinerator design. The plant listed in the 1954-1956 bar graph of Figure 3 represents New York City's new southside incinerator.

Grate Loading Factors

Grate loading design factors depend largely on the type of grate used and the type of refuse to be burned. Data on grate loading design factors were reported by 41 cities. These are listed in Table III according to type of refuse burned and type of grate used. Probably the outstanding characteristic of grate loading design evidenced by the data is their relatively wide variation in actual practice. For example, eight cities reported using rotary circular type furnaces for incinerating garbage and combustible rubbish. Grate loading factors reported varied from 25 to 120 or almost 500%. These plants were all constructed in the period 1949-1956. A somewhat similar relationship insofar as range is concerned exists in the case of plants with hand stoked type grates in their furnace or furnaces. In this instance, however, all the furnaces were constructed or installed prior to 1943 with one exception, a plant built in 1945. There were less data reported on plants using automatic or semi-automatic sloped grates. However, the range in grate design factors reportedly used in five plants designed to burn mixed refuse was about 50% (48-71 pounds per square foot per hour) a comparison of the median reported grate loading factors of plants using the three types of grates and handling the same type refuse (garbage and combustible rubbish) ranged from 64-76 pounds per square foot per hour, a variation of less than 20%.

Figure 3 GRATE TYPE USED VS. TIME (3YR. GROUPS) OF COMPLETION OF PLANT CONSTRUCTION (FOR 92 CITIES)

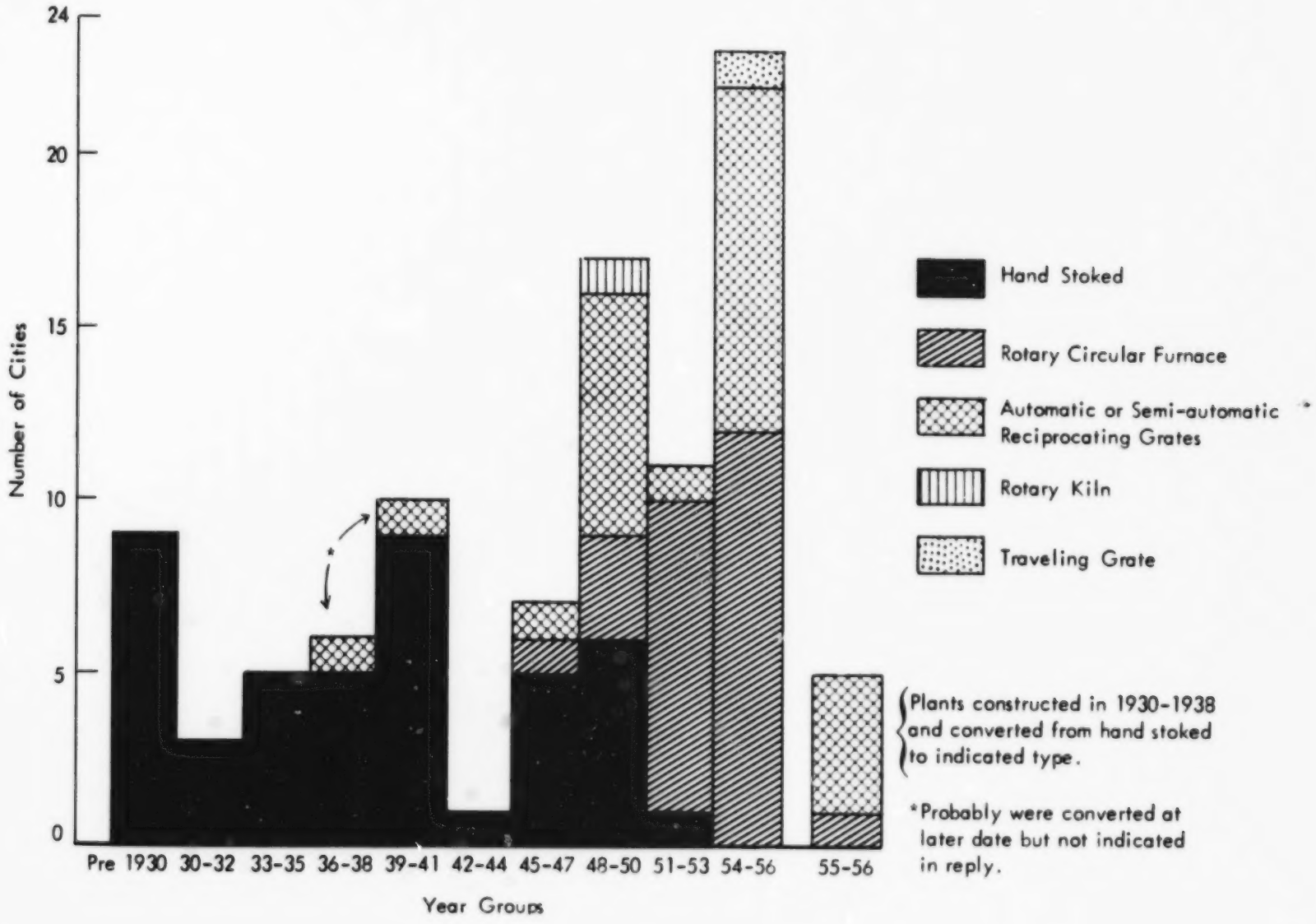


TABLE III

GRATE LOADING DESIGN FACTORS REPORTEDLY USED IN THE CONSTRUCTION OF 41 MUNICIPAL INCINERATOR PLANTS*

(lbs./ft.^{2}/hr.)

Type of Refuse Burned	Automatic or Semi-Automatic Sloped Grates	Rotary Circular Type Grates	Hand Stoked Type Grates
GCR	83	120	111
GCR	71	100	100
GCR	57	84	70
GCR	--	83	70
GCR	--	70	65
GCR	--	50	64
GCR	--	42	56
GCR	--	25	50
GCR	--	--	46
GCR	--	--	40
GCR	--	--	15
CR	--	100	--
CR	78	100	--
CR	51	80	--
CR	44	72	--
R	71	150	70
R	63	84	60
R	60	83	47
R	50	--	--
R	48	--	--
G	58	--	--

* One city reported a grate loading of 70 lbs./ft.^{2}/hr. used in a rotary kiln type plant burning garbage and combustible rubbish.

CODE: GCR - Garbage and Combustible Rubbish
CR - Combustible Rubbish
R - Refuse
G - Garbage

Furnace, Combustion and Flue Chamber Design Factors

The variation in furnace volume and secondary chamber design while substantial was not so pronounced in the various types of furnaces as in grate design factors. Listed in Table IV are the furnace volumes in terms of cubic feet per ton of rated capacity and the ratio of the combustion chamber volume and the flue volume respectively to the furnace volume according to type of grate and type of refuse burned.

For furnaces utilizing rotary circular type grates the median values of furnace volume design factors reported ranged from 9.6 to 11.6 cu. ft./ton of rated capacity for garbage and combustible rubbish, mixed refuse and combustible rubbish. The corresponding ratios of the combustion chambers and the flues to the furnace volume in the "median" plants were as follows:

	Furnace Vol. Cu. Ft./Ton of Rated Capacity	Ratio of Combustion Chamber Vol. to Furnace Vol.	Ratio of Flue Vol. to Furnace Volume
Garbage and Combustible Rubbish	9.6	2.8	---
Refuse	10.0	0.6	0.6
Combustible Rubbish	11.6	1.3	6.9

For furnaces using automatic or semi-automatic sloped grates the median values of furnace volume design factors ranged from 13.6 to 15.0 cu. ft./ton of rated capacity for garbage and combustible rubbish, mixed refuse, and combustible rubbish.

TABLE IV

FURNACE, COMBUSTION AND FLUE CHAMBER DESIGN FACTORS
REPORTEDLY USED IN THE CONSTRUCTION OF 36 MUNICIPAL INCINERATORS

Type of Refuse Burned	AUTOMATIC OR SEMI-AUTOMATIC SLOPED GRATES			ROTARY CIRCULAR TYPE GRATES			HAND STOKED TYPE GRATE		
	Furnace Vol. Cu. Ft./Ton of Rated Capacity	Ratio Combustion Vol. to Furnace Volume	Ratio Flue Volume To Fur. Vol.	Furnace Vol. Cu. Ft./Ton of Rated Capacity	Ratio Combustion Vol. to Furnace Volume	Ratio Flue Volume to Fur. Vol.	Furnace Vol. Cu. Ft./Ton of Rated Capacity	Ratio Combustion Vol. to Furnace Volume	Ratio Flue Volume to Fur. Vol.
GCR	24.0	1.3	3.16	11.0	1.4	1.1	23.2	0.40	0.40
GCR	13.6	1.2	0.05	10.4	1.9	---	15.0	0.67	----
GCR	10.0	0.96	----	10.0	0.60	0.6	12.2	1.4	0.07
GCR	----	----	----	10.0	0.45	0.9	12.0	1.0	----
GCR	----	----	----	9.9	2.9	---	11.0	1.5	1.5
GCR	----	----	----	9.2	2.8	---	6.8	---	---
GCR	----	----	----	9.2	1.7	0.81	5.0	---	---
GCR	----	----	----	9.0	1.9	1.0	---	---	---
GCR	----	----	----	8.0	2.5	---	----	---	---
GCR	----	----	----	7.0	2.1	---	----	---	---
CR	21.6	2.1	1.6	13.4	2.0	3.5	-----	---	---
CR	15.0	1.9	1.9	11.6	1.3	6.9	----	---	---
CR	14.0	2.3	14.8	7.5	1.8	2.0	----	---	---
R	17.0	2.4	0.10	11.0	2.9	2.3	16	1.1	0.74
R	15.0	0.8	0.13	10.0	0.6	0.6	13	1.5	0.31
R	14.0	2.1	----	9.0	1.9	1.0	---	---	---
R	10.0	1.5	4.85	---	---	---	---	---	---
G	5.8	0.25	0.43	---	---	---	---	---	---

CODE: GCR - Garbage and Combustible Rubbish. CR - Combustible Rubbish. R - Refuse. G-Garbage

The corresponding ratios of the combustion chambers and the flues to the furnace volume in the "median" plants were as follows:

	Furnace Vol. Cu. Ft./Ton of Rated Capacity	Ratio of Combustion Chamber Vol. to Furnace Vol.	Ratio of Flue Vol. to Furnace Volume
Garbage and Combustible Rubbish	13.6	1.2	0.05
Refuse	15.0	0.8	0.13
Combustible Rubbish	15.0	1.9	1.9

It is interesting to note that although the reported furnace volume design factors for the hand stoked plants varied from 5 to over 23 cu. ft. per ton of rated plant capacity, the median of the plants designed to incinerate garbage and combustible rubbish had a design factor of 12.0 cu. ft. per ton of rated capacity.

Based on the data reported, it is difficult to select "preferred" design factors. In fact, the data is consistant, generally, only in its inconsistency. It would seem a logical conclusion that considerable field investigation and research is needed to establish desirable standards of basic design for furnace, combustion, and flue chambers.

Stack Design Ratios

Thirty-six cities reported data on their newest or best plant which enabled the computation of the stack design volume and comparison with the rated furnace capacity assigned to each stack. Table V shows this comparison or ratio according to the type of refuse the plants were reportedly designed to burn. Again there was a wide variance. Some of this variance can be explained perhaps by the use of forced rather than natural draft. Although the data reported did not specify natural draft, interpretation of that which was reported indicated that the vast majority relied on natural draft for day to day operation. It should be recognized further, however, that extremes computed in this data may well be the result of inaccurately reported data due to misinterpretation of the questionnaire or other factors. A summary of the stack design ratio data is presented in Table VI.

TABLE V
STACK DESIGN RATIOS
A COMPARISON OF STACK VOLUMES AND RATED CAPACITIES
ACCORDING TO TYPE OF REFUSE BURNED

Type Refuse Burned	Rated Capacity Tons/day/stack	Stack Cross Section Area (sq. ft.)	Stack Ht. (ft.)	Stack Vol. (Cu. Ft.)	Ratio Stack Vol. to Rat. Cap.
Garbage and	500	78	176	13,700	27.4
Combustible	450	113	175	19,800	44.0
Rubbish	400	28	100	2,800	7.0
	300	79	183	14,500	48.4
	300	50	116	5,800	19.3
	300	100	179	17,900	59.7
	300	86	167	14,400	48.0
	300	76	175	13,300	44.3
	250	9	100	900	3.6
	240	28	100	2,800	11.7
	225	227	126	28,600	126.0
	200	50	125	6,250	31.3
	192	50	128	6,400	33.3
	192	16	80	1,280	6.7
	125	33	90	2,970	23.8
	100	20	100	2,000	20.0
	72	14	70	980	13.6
	60	14	83	1,160	19.3
	30	12	87	1,040	34.7
	27	138	61	8,400	311.0
Combustible	300	50	129	6,450	21.5
Rubbish	300	133	204	27,200	90.7
	250	95	166	15,800	63.2
	150	52	140	7,280	48.5
	120	20	70	1,400	11.7
	100	50	146	7,300	73.0
Combined Refuse	480	36	125	4,500	9.4
	400	150	175	26,200	65.5
	375	452	150	67,800	181.0
	300	113	150	16,900	56.3
	300	95	160	15,200	50.7
	225	50	125	6,250	27.8
	200	45	100	4,500	22.5
	200	75	175	13,100	65.5
	50	9	88	792	15.8
Garbage	150	13	30	390	2.6

TABLE VI
SUMMARY OF STACK DESIGN RATIOS
ACCORDING TO TYPE OF REFUSE BURNED

	Range of ratios (Stack Volume To Rated Capacity)	Median Plant	No. of Cities Reporting
Garbage and Combustible Rubbish	3.6 - 311	29	20
Combustible Rubbish	11.7 - 90.7	55	6
Mixed Refuse	9.4 - 181	51	9
Garbage	2.6	--	--

Charging Methods and Plant Storage Capacity

Satisfactory combustion depends not only on proper design but also, in large part, on proper operation. In recent years, the need for plant layout to facilitate storage of refuse as delivered to the plant in order to permit uniform charging over the operating day has been demonstrated to be of prime importance. With a few exceptions (depending primarily on climate and plant location within a city) pit and crane design is utilized to achieve sufficient storage capacity.

Figure 4 is a graphic presentation of the charging methods used in 100 municipal incinerators according to population group. As might be expected the vast majority of the plants constructed in cities having more than 100,000 population are of the pit and crane design. Recently conveyor systems have been introduced to further facilitate uniform charging of the furnaces. It is interesting to note that a substantial number of crane and bin type plants have been built in recent years in less than 25,000 population group.

Listed in Table VII are data on the storage pit capacity reported in 39 plants as compared with 24 hour rated capacity. The data is broken down according to type refuse burned in the plant and the year construction was completed. Again, the most constant factor seems to be the varying ratios with no particular relationship to whether the plant is many years old or

Figure 4 CHARGING METHOD USED IN 100 MUNICIPAL INCINERATORS ACCORDING TO POPULATION GROUP

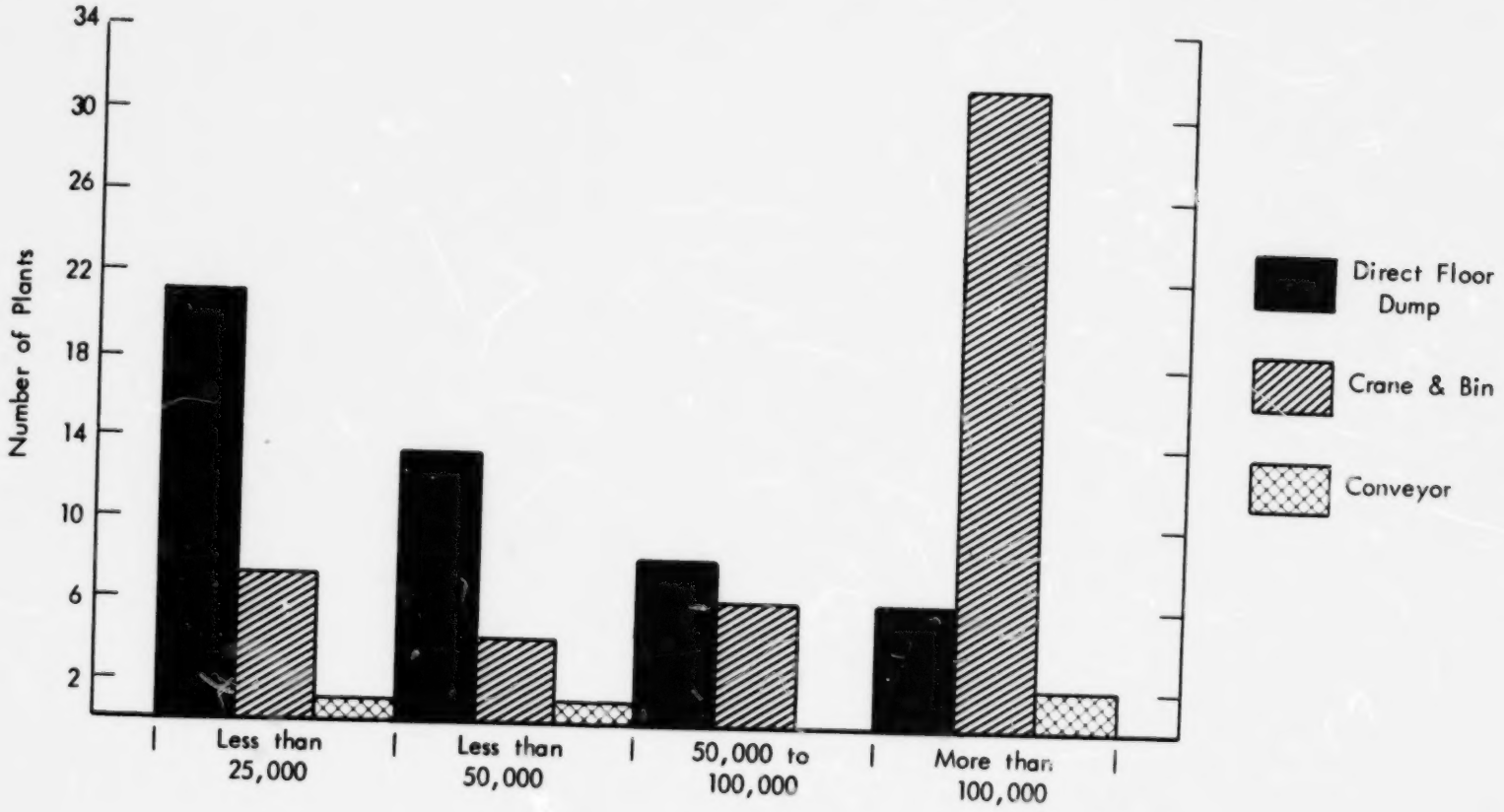


TABLE VII
STORAGE PIT CAPACITY OF 39 PLANTS
RATIO OF VOLUME OF PIT (CU. YDS.) TO RATED PLANT CAPACITY (TONS/24 HRS.) ACCORDING TO TYPE OF REFUSE BURNED

GARBAGE AND COMBUSTIBLE REFUSE		REFUSE	
Ratio of Pit Vol. (Cu. Yds.) to Rated Cap. of Plant	Year Plant Constructed	Ratio of Pit. Vol. (Cu. Yds.) to Rated Cap. of Plant	Year Plant Constructed
8.3	1949	28.0	1954
6.3	1936	10.0	1935
5.8	1955	6.0	1954
5.3	1955	5.9	1956
4.2	1950	5.0	1955
4.1	1954	5.0	1951
4.0	1940	4.7	1956
3.3	1951	4.0 *Median	1955
3.3	1939	4.0	1955
3.2 *Median	1939	3.9	1929
3.0	1956	3.2	1954
2.5	1954	3.0	1956
2.2	1953	2.9	1948
2.0	1948	1.9	1938
1.7	1941	1.3	1955
1.6	1950		
1.2	1952		
1.0	1939		
0.7	1955		

*The median value represents 16 hour storage capacity assuming the density of GCR as 350 lbs./cu. yd.

*The median value represents 24 hour storage capacity assuming the density of R as 400 lbs./cu. yd.

COMBUSTIBLE RUBBISH		GARBAGE	
Ratio of Pit Vol. (Cu. Yds.) to Rated Cap. of Plant	Year Plant Constructed	Ratio of Pit. Vol. (Cu. Yds.) to Rated Cap. of Plant	Year Plant
6.0	1954	0.3*	1948
3.3*	1956		
1.3	1950		

*Assuming a density of 200 lbs./cu. yd. this value represents about eight hour storage capacity.

*This value represents a 2 1/2 hr. storage capacity assuming the density of G as 1000 lbs./cu. yd.

recently built. The latter would seem to be particularly pertinent in view of the sharply increased volume of rubbish being produced in urban life in recent years. Data on 19 plants incinerating garbage and combustible rubbish showed a variance of pit storage capacity from 3-1/2 hours to 1-2/3 days, the median plant reporting a ratio of pit volume to rated plant capacity of 3.3 (16 hours storage assuming the density of garbage and combustible refuse as 350 lbs./cu. yd.). Fifteen plants reportedly burning mixed refuse reported pit storage capacities indicating ratios of 1.3 to 28.0. The median plant reported a ratio of pit volume to plant rated capacity of 4.0 which represented a 24 hour storage capacity assuming the density of mixed refuse as 400 lbs./cu. yd. A comparable amount of data on combustible rubbish and garbage incineration plants was lacking but that which was reported is included in Table VII.

Use of Licensed Engineer Operators

Ninety cities reported on whether licensed engineer operators were required in their municipal refuse incinerator plants. Eight-five replied negatively. Atlanta, Georgia; Minneapolis, Minnesota; Glouchester City, Massachusetts; Trenton, New Jersey; and Providence, Rhode Island; replied affirmatively.

Operational Employee Training Courses

Seventy-seven of the 89 cities reporting on whether formal operational employee training courses were given indicated no. The twelve cities listed below reported that some type of formal operational employee training courses were given:

Hartford, Connecticut	Youngstown, Ohio
Washington, D C.	Portland, Oregon
Jacksonville, Florida	Memphis, Tennessee
Brookline, Massachusetts	Fort Worth, Texas
St. Louis, Missouri	Fond du Lac, Wisconsin
Omaha, Nebraska	Shorewood, Wisconsin

Costs, Construction and Operation

Construction costs of municipal refuse incinerators depend not only on general construction cost trends but on many other local factors. For example, a direct floor dump plant can be constructed at a substantially less first cost than a pit and crane type plant. Similarly, construction

in a year-round, warm, dry climate permits design of a plant without many costly appurtenances including sometimes the building itself. For example, the Ft. Lauderdale, Florida, incinerator plant was constructed in 1954 at a unit cost of $1,700 per ton of rated capacity. This relatively low unit cost was achieved through limited building construction and appurtenances made possible by the climate and the isolated location of the plant.

Figure 5 shows construction costs (dollars per ton of rated capacity) for 59 municipal incinerator plants built during the period 1940-1956. The relatively sharp increase in costs is self evident, particularly in the period 1948-1956. In 1948 the median plant cost was in the area of $2,000 per ton of rated capacity. In 1956 this figure was $3,300 and apparently construction costs are rising at an increasing rate, probably because of a trend toward further mechanization.

Reported operational costs proved to be quite varied, but fell into a general geographic area pattern. Listed in Table VIII is a summary of personnel and maintenance costs according to geographic location for 60 cities. The normal range was arrived at by computing the upper and lower 1/4 points as well as the median of the reporting cities in each area. The median values of the Northeast, North Central and Southern areas were 252, 261, and 242 dollars per ton of rated capacity per year respectively. The median value for the Pacific Coast area was appreciably higher, $424 dollars per ton of rated capacity per year. The latter should be interpreted in light of the fact that only 6 cities (five from California) reported the necessary data to compute these costs.

Of further interest in analyzing costs are the effects of 8, 16, or 24 hour operation on plant maintenance and personnel figures. Data supplied by 61 cities permitted plotting costs of operation and plant maintenance as shown in Figure 6. This data indicates a decided advantage insofar as plant maintenance and personnel costs are concerned for 16 hour operation over 8 hour operation and also 24 hour operation over 16 hour operation. Thus the data indicates strongly that where it is possible to design a plant for 24 hour utilization rather than for 8 or 16 hour operation a substantial saving in operational costs may be realized.

Figure 5 CONSTRUCTION COSTS FOR 59 MUNICIPAL INCINERATORS, 1940-1956

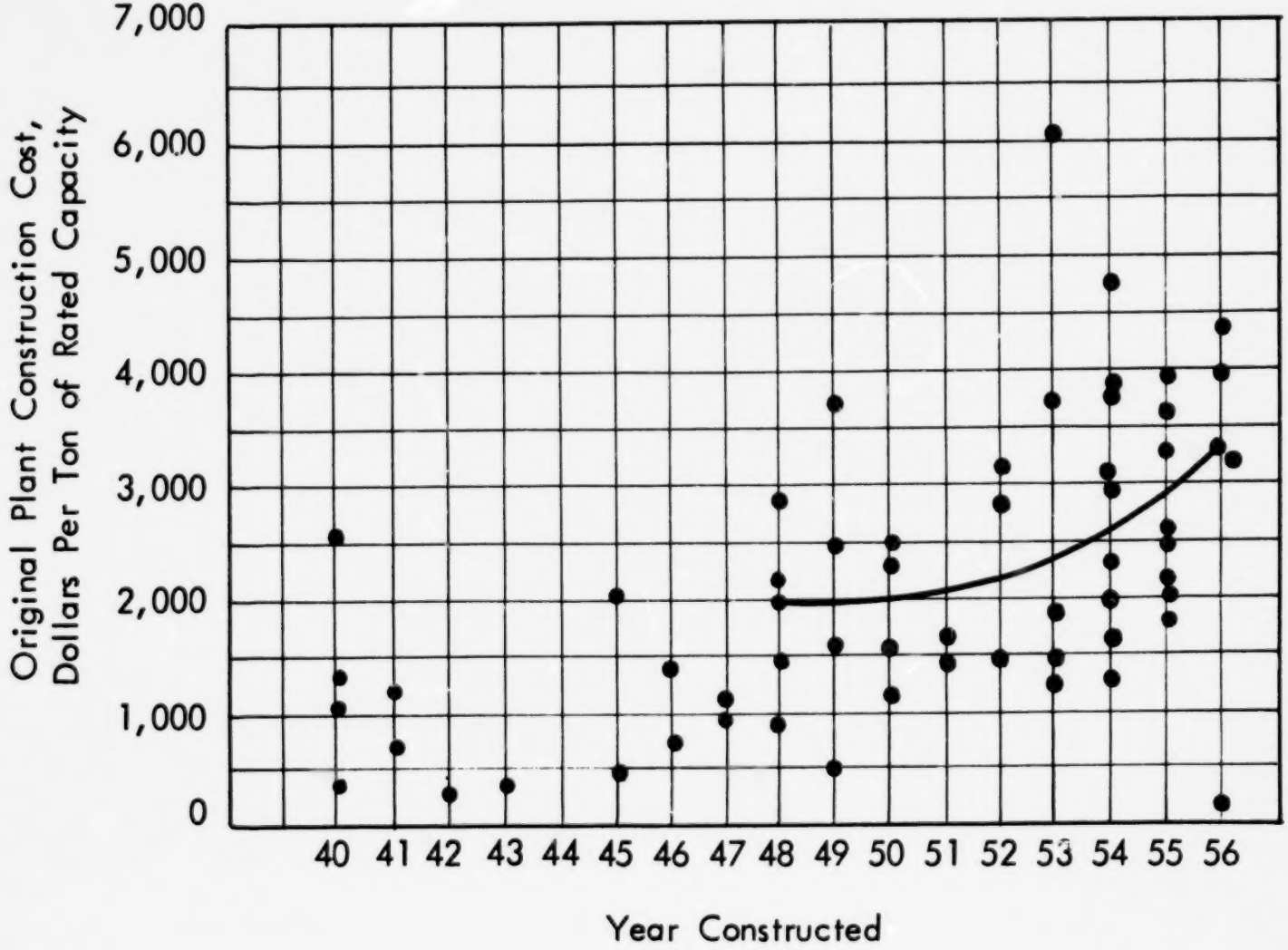


Figure 6 EFFECT OF 1, 2 AND 3 SHIFT OPERATION ON OVERALL PLANT MAINTENANCE AND PERSONNEL COSTS* IN 61 CITIES, 1956 (ON A PER FURNACE BASIS)

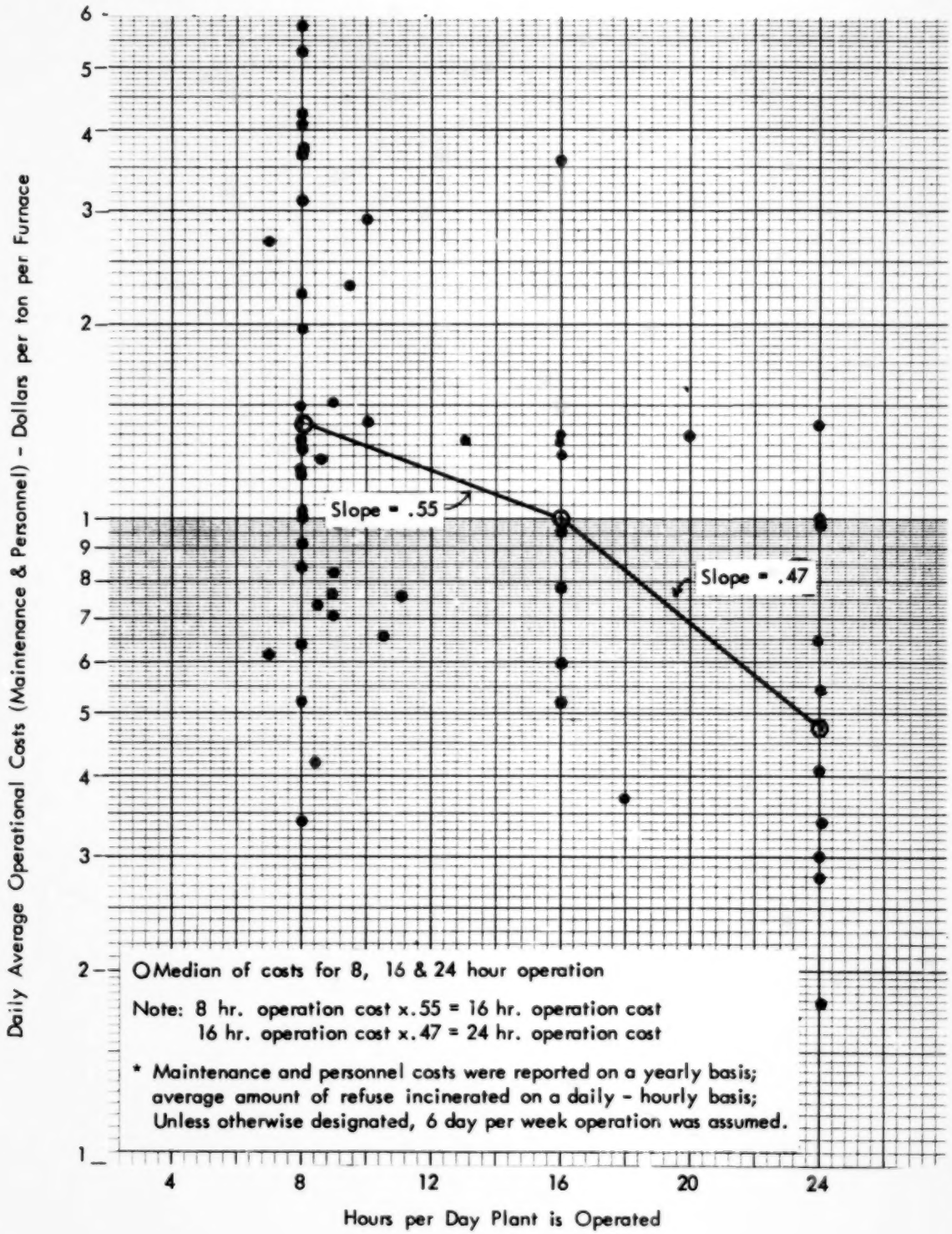


TABLE VIII
A SUMMARY OF PERSONNEL AND MAINTENANCE COSTS
ACCORDING TO GEOGRAPHICAL LOCATION*
(DOLLARS PER TON OF RATED CAPACITY PER YEAR)

	North East (22 Cities)	North Central (21 Cities)	South (11 Cities)	Pacific (6 Cities)
Maximum	580	714	393	716
Upper 1/4 pt.	388	521	350	550
Median	252	261	242	424
Lower 1/4 pt.	218	153	104	143
Minimum	98	90	94	120

*

North East:	Massachusetts, Connecticut, New York, New Jersey, Delaware, Maryland, and District of Columbia.
North Central:	Ohio, Illinois, Michigan, Wisconsin, Minnesota, Missouri, and Nebraska
South:	Texas, Virginia, West Virginia, Georgia, and Florida.
Pacific:	Oregon and California.

The median of reported 8, 16, and 24 hour operational and maintenance costs were $1.40, $1.00, and $.48 per ton per furnace/day respectively.

Auxiliary Fuel

Eight-eight cities reported on whether auxiliary fuel was ordinarily needed to complete incineration. Seventy-three indicated auxiliary fuel was not needed ordinarily although 13 or 17% of this number indicated it was used at least once during the previous full year (1956). Fourteen cities replied that auxiliary fuel was either ordinarily or occasionally needed. Ten of the 14 indicated garbage and combustible rubbish was the type of refuse burned; two specified garbage; and two specified mixed refuse.

Air Pollution Aspects

Recently, the air pollution aspects of municipal incinerator design and operation has taken an increased significance. For the purposes of this survey, potential plant nuisances were divided into three categories: noise, odor and fly ash problems. Eighty-four cities reported that they

received no complaints in regard to noise resulting from operation of their plants. Eighty-six cities reported on odor nuisances; of this number 85 reported the absence of complaints and only one indicated odor nuisance was a problem. This was a plant originally constructed in 1939 and designed to burn mixed refuse.

In regard to fly ash 51 of the potential 87 cities replied. Thirty-nine indicated no fly ash nuisance complaints. However, 12 or about 25% of the reporting group did indicate there were fly ash nuisance complaints.

As a matter of general interest the responsible officials in the various cities were queried as to whether air pollution standards were taken into account when the plant was designed. Fifty-five replied that some type of air pollution standards were taken into account. Twenty-two or almost 30% of the reporting cities indicated such standards were not. Of the 55 cities stating that air pollution standards were taken into account, 43 indicated that their plant complied. Five indicated that their plant did not and six indicated they had no information on this factor. The air pollution standards given as points of reference varies from simple use of a Ringleman chart as a base reference to such criteria as 0.30 gr./cu. ft. corrected to 50% excess air and 500° F.

CONCLUSIONS

The considerable variety in the construction and operational characteristics of municipal incinerators are indicative of a need for further research and development to assure more efficient design parameters.

A definite trend toward further mechanization has been noted in the survey data.

There is an apparent need for more careful training of technical and other personnel concerned with municipal incineration.

The problem of air pollution caused by the incineration process is gaining considerable recognition and demands additional investigation.

CREDIT

This survey report is one of a series of professional contributions sponsored by the A. S. C. E. Committee on Sanitary Engineering Research:

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REPORTING CITIES

ALABAMA
- Birmingham

CALIFORNIA
- Alhambra
- Los Angeles
- Pasedena
- Santa Monica
- Signal Hill

CONNECTICUT
- Darien
- Greenwich
- Hartford
- Middletown
- New Britain
- New Canaan
- Waterbury

DELAWARE
- Wilmington

DISTRICT OF COLUMBIA
- Washington

FLORIDA
- Coral Gables
- Ft. Lauderdale
- Jacksonville
- Miami

GEORGIA
- Atlanta

ILLINOIS
- Chicago
- Oak Park

IOWA
- Clinton

LOUISIANA
- New Orleans

MARYLAND
- Baltimore
- Frederick
- Salisbury

MASSACHUSETTS
- Brookline
- Fall River
- Framingham
- Lawrence
- New Bedford
- Newton
- Waltham
- Worcester

MICHIGAN
- Detroit
- Highland Park
- Muskegon
- Oakland County

MINNESOTA
- Minneapolis
- Montevideo
- St. Cloud

MISSOURI
- St. Louis
- St. Louis Park

NEBRASKA
- Omaha

NEW JERSEY
- Gloucester City
- Princeton
- Trenton

NEW YORK
- Babylon
- Buffalo
- Corning
- Hempstead
- Huntington
- Mechanicville
- Middletown
- New York City
- Rochester
- Schenectady
- Tonawanda
- Yonkers

NORTH CAROLINA
- Concord
- Durham

OHIO
- Barberton
- Bedford
- Cincinnati
- Cleveland
- Cuyahoga Falls
- Dayton
- East Cleveland
- South Euclid
- Warren
- Youngstown

OREGON
- Portland

PENNSYLVANIA
- Beaver Falls
- Oil City
- Philadelphia
- Sewickley

RHODE ISLAND
- Newport
- Providence

TENNESSEE
- Jackson
- Memphis

TEXAS
- Fort Worth
- Houston

VIRGINIA
- Alexandria
- Arlington
- Newport News
- Norfolk
- Portsmouth
- Radford
- Staunton

WEST VIRGINIA
- Charleston

WISCONSIN
- Fond Du Lac
- Green Bay
- Kenosah
- Merrill
- Milwaukee
- Monroe
- Oconomowac
- Sheboygan
- Shorewood
- West Bend

MANATOBA
- Winnepeg

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MUNICIPAL INCINERATOR PLANT SURVEY

1. State _____ 2. City _____

3. Plant Name _____ 4. Year Built _____

5. a. Capacity _____ tons /hr.
   b. Average amount actually burned _____ tons /hr.

6. Material acceptable for burning
   a. Rubbish (comb. or non-comb.) ( )
   b. Combined or mixed refuse ( )
   c. Combustible rubbish only ( )
   d. Garbage (waste food) ( )
   e. Garbage and comb. rubbish ( )

7. Who was responsible for engineering the plant?
   a. Manufacturer ( )
   b. Consulting engineer ( )
   c. Municipal engineering staff ( )
   d. Are you satisfied with plant's performance? Yes ( ) No ( )

8. a. Do you also dispose refuse in sanitary landfills? Yes ( ) No ( )
   b. Incinerator ash is disposed in sanitary landfills? Yes ( ) No ( )

9. Design data
   a. Do you weigh refuse to be burned? Yes ( ) No ( )
   b. Number of furnaces _____
   c. Design grate loading _____ lb./sq.ft./hr.
   d. Grate type: Rotary kiln ( )
      Rotary circular furnace ( )
      Automatic or semi-automatic reciprocating sloped grates ( )
      Hand stoked ( ) Other ( )
   e. Furnace volume _____ cu.ft./ton of rated capacity
   f. Charging method: Direct floor dump ( ) Crane and bin ( )
      Conveyor ( )
   g. Secondary chamber vol. _____ cu.ft./ton of rated capacity
   h. Flue vol. _____ cu.ft./ton of rated capacity

9. i. Stack cross-sectional area _____ sq.ft.
   j. Stack height _____ ft.
   k. Storage pit volume _____ cu.yds.

10. Operational data
   a. Are licensed engineer operators used? Yes ( ) No ( )
   b. Do you have any type of formal operational employee training courses? Yes ( ) No ( )
   c. Original plant cost $_____
   d. Maintenance cost per year $_____
   e. Personnel cost per year $_____
   f. Number of employees _____
   g. Number of hours operated daily ___
   h. Charge to private haulers of refuse $_____ /ton
   i. Is there complaint on plant odor nuisance? Yes ( ) No ( )
      Noise? Yes ( ) No ( )
      Fly Ash? Yes ( ) No ( )
   j. Is auxiliary fuel ordinarily needed? Yes ( ) No ( )
      If No, was it used last year? Yes ( ) No ( )

11. Stack discharge
   a. Were air pollution standards taken into account in designing the plant? Yes ( ) No ( )
      If so, does the plant performance comply? Yes ( ) No ( )
      Unknown ( )

12. Total number of municipal incinerator plants in operation _____

13. If available, a copy of the original incinerator design report, annual operating reports, and the air pollution standards your plant is requested to meet would be most helpful.

14. Name of reporting official: _____

15. Date: _____

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